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# A Visualized Review of Ecological Planning and Design based on Bibliometrics from 1992 to 2017

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**Abstract:** To rapidly and clearly define the knowledge structure, research focus, and research trends in the field of ecological planning and design, the bibliometric method was combined with visualization tools to conduct a classified statistical study of 712 articles on ecological planning and design in the core database of Web of Science (WoS) from 1992 to 2017, making a contrastive analysis of information like the author, journal, research institution, country, keywords of those articles from three perspectives, namely co-authorship analysis, co-citation analysis, and co-words analysis. Three conclusions were drawn. First, academic exchanges and cooperation in the field of ecological planning and design should be strengthened between countries and scientific research institutions, especially China and its research institutions should actively participate in such exchanges and cooperation, and scholars are expected to seize the opportunities to cooperate with each other in research and practice in this field. Second, as developed European and American countries outweigh Asian countries in terms of research results and overall influence in the field of ecological planning and design, the popularity and influence of journals from Asian countries need to be improved, particularly as they study and report on ecosystem services. Third, as research on ecological planning and design has become increasingly systematic, comprehensive, and humanistic, resilience has become a research hotspot in this field in recent years, thus enough attention should be paid to this aspect. Finally, the author hopes that the combination of visualization tools and the bibliometric method can foster enlightenment and research ideas among researchers and practitioners in this field.

## 1. INTRODUCTION

The world is changing at an unprecedented speed and is becoming increasingly complex, integrated, and uncontrollable. The planet has many diverse cultures and unique ecological systems, yet economic, technological, and scientific transformations are forces that have incessantly affected the earth and had a profound impact upon its fragile social and ecological structures. In fact, the problem of the coexistence between humanity and nature has existed since the emergence of humankind. Before the dawn of

modern technology, this problem stemmed from human limitations in terms of their ability to radically transform nature in their productive endeavours. Also, their general awe at the presence and creativity of mysterious nature played a factor here. The situation changed in the early 20<sup>th</sup> century, and negative impacts from human behaviour upon the earth's landscape have accumulated over the past century. Ecological planning, as a way of coordinating human behaviour and ecological protection, has gained acceptance as a viable institution at the same time as environmentalists have awakened to the need to protect nature, and science, knowledge, and information have attained explosive growth ([Bennett et al., 2016](#); [Blondel, 2006](#)).

As an ecology-based application strategy that is beneficial for both humankind and nature, ecological planning has been inextricably linked to ecological design—this has happened to such an extent that the latter is often taken to be a synonym for the former. Yet while related, the two fields are in fact different. The biggest difference between ecological planning and ecological design may be that the latter practices at a relatively smaller scale (e.g., on the level of small parks and courtyards) as compared with the former. Therefore, the intervention of social culture and user's preference in ecological design greatly exceeds the level that is brought into ecological planning. In fact, designers must carry out ecological design based on regional culture, so as to ultimately ensure the identity of ecological design culture and the continuation of innovation, eco-design, and enhance the overall functions of ecosystem services ([Nassauer, Wang, & Dayrell, 2009](#)). In the United States, ecological planning and design originates from landscape planning and design courses offered by institutions of higher education. McHarg's (1969) suitability evaluation method has opened a new window for people to understand ecological planning and design, and the ecological planning method conceived therein is of epoch-making significance ([McHarg, 1969](#); [Yang & Li, 2016](#)). Currently, research achievements and practical achievements in ecological planning abound; these extensively involve practical fields such as ecology, agriculture, design, geography, and sociology ([Legendre et al., 2002](#); [Zhao et al., 2016](#)). These achievements place greater emphasis upon effective and suitable practice ([Xiang, 2014, 2016](#)), as well as systematic, humanistic, and comprehensive theories ([Ban et al., 2013](#); [Bartuszevige et al., 2016](#); [Moraine, Duru, & Therond, 2017](#)).

In the past half century, the results of a large number of studies about ecological planning and design were disseminated through media such as books, periodicals, and articles; the emergence of the Internet since the mid-1990s caused explosive growth in the knowledge of this field. To grasp the academic trends and research progression in a specific field of study, researchers usually need to review a copious amount documents and then professionally screen and summarize them. Though this traditional method prevails today and is irreplaceable, it is time consuming to search the massive number of documents among an equally massive number of journals and other sources. Also, researchers are susceptible to subjective factors such as their own academic levels and preferences, so it is difficult for them to present both clearly and objectively the history of development, the major research topics and themes, the points of focus, and the current trends and directions of specific research to the readers. In view of this, this study combines bibliometrics with visualization tools in order to explore the field of ecological planning and design so as to gain a better understanding of the current situation of the field as well as to identify the latest progress of research in it. This is done with the hope of providing a theoretical basis for future researchers and practitioners.

## 2. METHOD

### 2.1 Visualization Tool

As the key to visualized analysis, reasoning and decision-making are considered as the second generation of computer-supported visual thinking after information visualization. According to Gestalt psychology theory, only by regarding relevant information as a whole can meaningful attributes be revealed. The purpose of information visualization is to gain a profound insight into complex and abstract information. In addition to helping researchers find specific information, information visualization also provides various methods for pattern and relationship identification that greatly help researchers optimize their search strategies. Currently, the frequently applied visualization tools include the CiteSpace software developed by the Chinese American [Chen \(2006\)](#), the VOSviewer and CitNetExplore software developed by [van Eck and Waltman \(2009\)](#), and the Pajek software developed by [Batagelj and Mrvar \(1998\)](#). CiteSpace and VOSviewer are employed for scientific measurement and visualized analysis. CitNetExplore is employed in citation networking and visualization. Pajek is employed in network visualization analysis.

CiteSpace was developed using the Java language and mainly measures a collection of documents in a certain field based on the pathfinder network scaling algorithm (PF-NET) and the co-citation analysis theory. CiteSpace shows the evolution path of specific scientific fields as well as cutting-edge information through diversified visualization maps. Based on the design philosophy of ‘changing the way we look at the world’, CiteSpace has creatively integrated both diachronic and structural analyses through citation analysis and co-citation analysis, respectively. In this way it creates a theoretical model map from the ‘knowledge base’ to the ‘research frontier’. Mapping knowledge domains can unify the visual thinking, mathematical thinking, and philosophical thinking of human researchers as they strive towards an understanding of the world to form the dual nature and characteristic combining ‘graph’ and ‘spectrum’, which fully shows the implicit but complex relationships between knowledge units or groups such as network, structure, crossover, and evolution ([Chen, 2006, 2017](#)). Due to the complexity, interdisciplinarity, and chronicity of ecological planning and design, as well as other factors, CiteSpace was used as the bibliometric analysis tool in this study. Its powerful functions in scientific metrology and visualized analysis as well as the extensive applicability and readability of the information that it applies.

### 2.2 Data Sources

Scientific text data collection is the basis of visualized analysis. Covering the fields of natural sciences, social sciences, engineering technology, arts and humanities, among others, the Web of Science (WoS) database contains highly influential academic journals from the world over that are both comprehensive and authoritative. In addition, as the data analysed by CiteSpace are based on WoS, there is no need for data conversion. In fact, the data structure of WoS is more complete than that of other databases such as Derwent and CSCI ([Wang et al., 2016](#)).

In view of the excellent data features of WoS and its seamless connection with CiteSpace, all the data used in this study are all from the WoS database.

On November 12, 2017, the data were searched through the Web of Science™ Core Collection via electronic resources provided by the Library of Northwest Agricultural & Forestry. The time span of the data searched is ‘ALL YEARS’ and the search field is ‘TITLE: (ecological planning) OR TITLE: (ecological design) AND DOCUMENT TYPES: (Article)’. A total of 712 articles spanning from 1992 to 2017 were obtained after the parameter setting. In addition, the author used the function of WoS called ‘Analyze Results’ to collect relevant data information of the articles, e.g., publication year, author, institution, country, etc., to get prepared for a further descriptive statistical analysis of them.

### 2.3 Analysis Methods

CiteSpace (V5.1.R6 SE 64bit) was used to analyse and study the data. The main analysis parameters were set as follows: The functional zone of Time Slicing was selected from 1992 to 2017, with the value of Years Per Slice being 1; Top N of Selection Criteria was equal to 50; ‘pathfinder’ was set as the way of network pruning. As for the functional zone of Visualization, which is mainly used to set the visualization results, the options of Cluster View-Static and Show Merged Network were selected; the Cosine algorithm was chosen to calculate the connection strength between the object data to be analysed (located in the functional zone of Links):

$$\text{Cosine}(c_{ij}, s_i, s_j) = \frac{c_{ij}}{\sqrt{s_i s_j}} \quad (1)$$

where  $C_{ij}$  denotes the co-occurrence frequency of  $i$  and  $j$ ,  $S_i$  is the occurrence frequency of  $i$ , and  $S_j$  is the occurrence frequency of  $j$  ([Ruan et al., 2016](#)).

In the end, the measuring indexes were calculated and ranked in Excel 2013, and the diagrams to present the data were drawn in Origin Pro 9.2.

## 3. RESULTS AND DISCUSSION

### 3.1 Analysis of the Quantity of Published Articles

*Figure 1* shows that the quantity of published articles on ecological planning and design featured a wavelike rise between 1992 and 2017. In 1997, there were only three articles, the lowest point of this twenty-five-year period. The number peaked at 80 in 2016, accounting for 11.2% of the total quantity of articles. The article quantity declined year by year between 1992 and 1994 and, in a more pronounced decline, between 1995 and 1997. After 1998, the annual article quantity increased with fluctuations, and the growth rate accelerated with each passing year. By 2016, the annual article quantity increased about nine times over that of 1998. As not all the articles published in 2017 have yet been collected and indexed, by November 12, there were only 41 articles; judging from the trend, however, the quantity in 2017 is not expected to exceed that of 2016.

According to currently available statistical information, the exponential growth model showing the inter-annual variation of article quantity and the cumulative article quantity was fitted based on the growth pattern of the article quantity:  $y = \exp(2.8226 + 0.1833x - 0.0015x^2)$ ,  $R^2 = 0.9888$ . As indicated by the maximum value of the fitting model for the accumulative article

quantity, it is predicted that the cumulative quantity of articles in the field of ecological planning and design will reach its peak in 2053, at a total of 4,548 articles. It can be seen that ecological planning and design is a topic that is being persistently researched in the current context, in which there is wide consensus that ecological degradation is building towards crisis point.

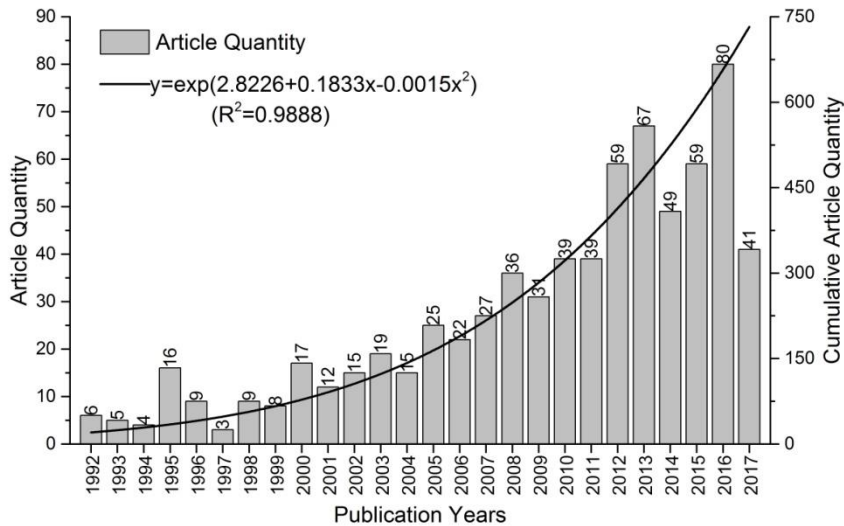


Figure 1. The exponential growth model showing the inter-annual variation of article quantity and the cumulative article quantity in WoS from 1992 to 2017

### 3.2 Co-Authorship Analysis

According to Price, father of scientometrics, co-authored articles have been growing linearly ever since the 20<sup>th</sup> century. Price predicts that the average number of co-authors will increase with the in-depth development of interdisciplines and edge disciplines (Price & Beaver, 1966). Scientific cooperation means researchers work together for the common goal of producing new scientific knowledge. In practical work, the forms of scientific cooperation usually involve co-authorship, co-institution, and co-country (Beaver & Rosen, 1978, 1979). CiteSpace analyses the collaborative network at three levels, the microlevel, the mesolevel, and the macrolevel, with the respective node types being author, institution, and country.

The co-authors in the field of ecological planning and design were clustered into 412 groups in CiteSpaceV. Of these groups, 164 have two or more group members; the cooperation networks of co-authors are relatively scattered, indicating that researchers in this field are not cooperating closely enough in practical work. Figure 2 shows the local networks of co-authors and the top seven clusters with the number of group members greater than or equal to 10. The font size of a cluster is proportional to its article quantity. Similarly, the font sizes of the author names in black are also proportional to the number of times that their articles have been cited. In addition, the colour of the tree ring history corresponds to citation time of the time slice, and the overall size of the tree ring history nodes next to the author's names reflects the citation frequency of their articles.



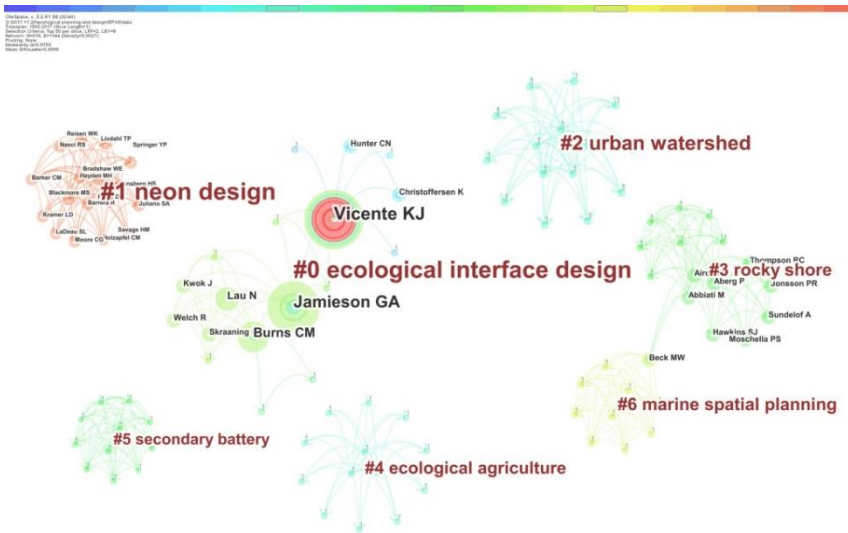


Figure 2. Local networks and the largest seven clusters of co-authors

As can be seen from *Table 1* and *Table 2*, the largest cluster (#0) contains a total of 18 articles. The article by Vicente K.J. has been cited 8 times since it was first cited in 2002 and has a burst value (reflecting sudden increases of attention or heat given to a story within a short period of time; denoted by red nodes) reaching as high as 3.47. Cluster (#0) ranks in first place among all the articles in both citation count and burst value. Jamieson G.A. and Burns C.M. rank second and third, respectively, in cluster (#0) in terms of citation count. The log-likelihood ratio (LLR) algorithm and mutual information (MI) algorithm were used to extract the research focus, ‘ecological interface design’ and ‘fault diagnosis’ of cluster #0. ‘Ecological interface design’ refers to a concept of generalized ecological design in the field of computer technology and information technology rather than a concept of ‘ecological design’ within the scope of ecology or landscape architecture. Although it has little to do with this study, it reveals the extension process of the connotation of ‘ecological design’ in a narrow sense (Vicente, 2002). In addition, since cluster #1 and cluster #5 almost have nothing to do with this study, they will not be discussed in detail.

Table 1. The top-ranked items of co-authors by citation count

| Frequency | First author   | Year | Half-life | Burst | Cluster |
|-----------|----------------|------|-----------|-------|---------|
| 8         | Vicente K.J.   | 1996 | 2         | 3.47  | 0       |
| 7         | Jamieson. G.A. | 2000 | 7         | –     | 0       |
| 4         | Hoekman D.     | 2016 | 0         | –     | 25      |
| 4         | Burns C.M.     | 2003 | 5         | –     | 0       |
| 4         | Opdam P.       | 2003 | 4         | –     | 8       |
| 4         | Battisti C.    | 2003 | 8         | –     | 103     |
| 4         | Deng Y.        | 2012 | 0         | –     | 31      |

As indicated by *Table 1*, the citation counts of Hoekman D., Opdam P., Battisti C., and Deng Y. are comparatively high. They focused on aquatic science (#25), large mammals (#8), ecological network planning (#103), and ecological restoration planning (#31), respectively, in their clusters. It is noteworthy that the half-life value of Battisti C. is the highest (burst = 8). In general, the higher the half-life value is, the more classical the article is, since it is frequently and consistently cited. However, in cluster #103, Hanna’s study is more representative and practically instructive. Based on the successful cases of regional protection of rural landscapes and natural habitats

in Toronto, Canada, [Hanna, Webber, and Slocombe \(2007\)](#) deeply explored the implementation process and comprehensive methods of regional ecological planning in the context of rapid urban growth.

*Table 2.* Summary of the largest seven clusters of co-authors

| Cluster | Size | LLR (Log-likelihood ratio, $p$ Value)         | MI (Mutual information) | Citee Year |
|---------|------|---|-------------------------|------------|
| 0       | 18   | ecological interface design (1888.94, 1.0E-4) | fault diagnosis         | 2002       |
| 1       | 17   | neon design (2500.47, 1.0E-4)                 | phenology sampling      | 2016       |
| 2       | 15   | urban watershed (1020.22, 1.0E-4)             | ecological benefit      | 2000       |
| 3       | 15   | rocky shore (1917.03, 1.0E-4)                 | benthic organism        | 2005       |
| 4       | 13   | ecological agriculture (1441.47, 1.0E-4)      | ecological agriculture  | 2000       |
| 5       | 11   | secondary battery (437.9, 1.0E-4)             | –                       | 2004       |
| 6       | 10   | marine spatial planning (759.12, 1.0E-4)      | ecological principle    | 2009       |

The statistical data in *Table 2* show that the research focus of cluster #3 and cluster #6 is oceanic watersheds. Cluster #3 probes into the phenomenon of habitat fragmentation caused by coastal defence projects where global warming may lead to sea level rise. Cluster #3 also addresses questions like how ecological standards should be used in design ([Moschella et al., 2005](#)). The researchers in cluster #6 argue that a sudden decline in the service function of a marine ecosystem requires a new ecosystem-based approach to maintain and restore biological diversity and integrity; moreover, it is extremely important for marine space planners to acquire professional knowledge, the key process to maintain the operation of this system and the degree of human-induced disruption, and profoundly recognize the resistance and resilience of environmental stress ([Crowder & Norse, 2008](#); [Foley et al., 2010](#)). Clusters #2 and #4 focus on ecological problems on the urban scale: Cluster #2 focuses more on the assessment of ecological benefits such as urban watersheds and urban forests ([Hession et al., 2000](#)) while Cluster #4 mainly discusses topics for ecological agriculture planning and education ([Lieblein et al., 2000](#)).

*Figure 3* shows a screenshot of the largest sub-network of the co-institution network. As can be clearly seen in the figure, many research institutions are interconnected by different coloured lines, suggesting close cooperative relationships between these research institutes in the field of ecological planning and design. It is also possible to see some relatively isolated clusters or dot networks, indicating a lack of extensive cooperation between one institution and other research institutions.

*Table 3.* The top ranked items of co-institution by citation count

| Frequency | Full institution names                     | Year | Half-life | Burst | Cluster |
|-----------|--|------|-----------|-------|---------|
| 15        | Chinese Academy of Sciences                | 2005 | 9         | –     | 7       |
| 13        | University of Toronto                      | 1998 | 7         | 3.72  | 1       |
| 10        | The University of Queensland               | 2005 | 7         | –     | 3       |
| 8         | James Cook University                      | 2010 | 5         | –     | 2       |
| 7         | Colorado State University                  | 2001 | 14        | –     | 5       |
| 7         | Texas Agriculture and Mechanics University | 2001 | 9         | –     | 10      |
| 7         | University of British Columbia             | 2003 | 10        | –     | 2       |
| 6         | The Nature Conservancy                     | 2002 | 8         | –     | 4       |
| 6         | Oregon State University                    | 1999 | 11        | –     | 4       |
| 6         | Delft University of Technology             | 2001 | 9         | –     | 15      |



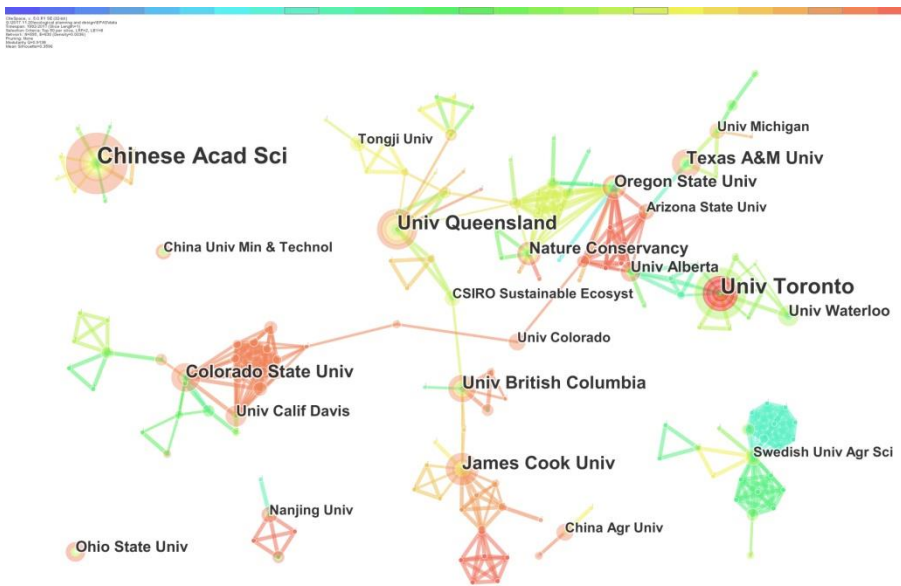


Figure 3. The largest sub-networks of co-institution

As indicated by *Table 3* and *Figure 3*, in addition to the Chinese Academy of Sciences, research institutions such as the University of Toronto, the University of Queensland, James Cook University, Colorado State University, Texas Agriculture and Mechanics University, University of British Columbia, the Nature Conservancy, Oregon State University, Delft University of Technology, among others not only have a high citation frequency; they also exist in the largest sub-network of studies on ecological planning and design, indicating that they have a high level of international cooperation. Located in Shanghai, an open coastal city in China, Tongji University, with the same level of professionalism, is also included in the largest sub-network. Chinese higher institutions such as Nanjing University and China Agricultural University failed to carry out co-institution research, though their articles are also frequently cited.

It is worth mentioning that the Chinese Academy of Sciences, as the famous scientific research institute with the highest citation rate (Freq = 15), seems to be isolated in co-institution in the field of ecological planning and design. One of the reasons may be that the research focus of the Chinese Academy of Sciences in the field of ecological planning and design is fragmented and differs greatly from the research content of other institutions. The second possible reason may lie in the late entry of the Chinese Academy of Sciences into research in this domain. According to *Table 3*, the Chinese Academy of Sciences conducted its first research in this field in 2005. Nevertheless, the relatively high half-life value of the Chinese Academy of Sciences shows that this institution does have some frequently cited high-quality, classic articles on ecological planning and design. Regardless of being a relative latecomer, the academy shows promising momentum toward and prospects for development.

*Figure 4a* is a general graph of co-country networks. The node size in the figure is positively correlated with citation frequency—i.e. the larger the node is, the more frequently the article is cited. In addition, nodes of the same colour indicate that they are in the same cluster. For example, the nodes indicating China and America in *Figure 4a* are approximately the same in size. Referring to the citation counts in *Table 4*, it can be seen that the citation

frequency of China is only one digit more than that of America. China, Australia, and England are of the same colour, and as shown by the Cluster ID in Table 4, all three countries are in cluster #1. As indicated by relevant calculation and statistical analysis, the top three countries with the highest citation count in each cluster are as follows: Austria (7), Switzerland (7), and Belgium (6) in cluster #0; China (174), Australia (42), and England (32) in cluster #1; Canada (61), Sweden (19), and France (18) in cluster #2; America (173), Japan (11), and South Korea (11) in cluster #3; and Germany (38), Mexico (8), and Russia (5) in cluster #4.

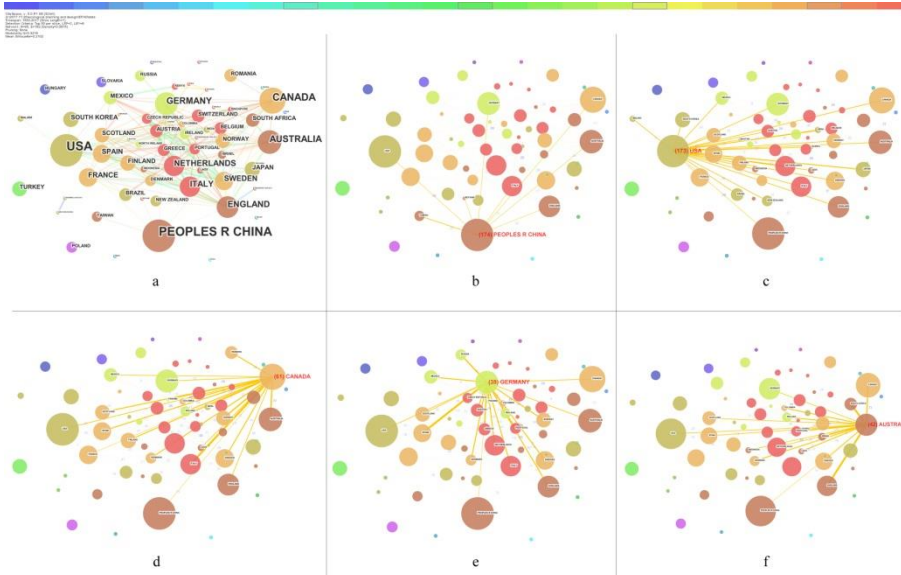


Figure 4. Networks of co-country

Table 4. The top ranked items of co-country by centrality

| Centrality | Country   | Frequency | Half-life | Burst | Year | Cluster ID |
|------------|-----------|-----------|-----------|-------|------|------------|
| 0.39       | America   | 173       | 19        | 4.58  | 1992 | 3          |
| 0.13       | Australia | 42        | 20        | –     | 1992 | 1          |
| 0.13       | Germany   | 38        | 14        | –     | 1997 | 4          |
| 0.13       | Austria   | 7         | 7         | –     | 2003 | 0          |
| 0.12       | Italy     | 26        | 13        | –     | 1998 | 0          |
| 0.11       | Canada    | 61        | 16        | 3.51  | 1993 | 2          |
| 0.11       | Scotland  | 10        | 7         | –     | 2006 | 2          |
| 0.1        | China     | 174       | 17        | 13.6  | 1996 | 1          |
| 0.1        | England   | 32        | 18        | –     | 1995 | 1          |

Table 4 ranks the nodes based on centrality value. The higher the centrality value is, the more important the node is and the more likely it is a key hub linking two distinct fields. Countries with a centrality value higher than 0.1 ranked from the highest to the lowest are America (0.39), Australia (0.13), Germany (0.13), Austria (0.13), Italy (0.12), Canada (0.11), and Scotland (0.11). Although the citation count of Austria is very small, Austria plays an important role of connection in national scientific research cooperation. As shown in Figure 4c (America), Figure 4d (Canada), Figure 4e (Germany), and Figure 4f (Australia), the co-country networks between these four countries are very densely connected while the co-country network of China (Fig. 4b) is sparsely connected, thus verifying the data in Table 4 again.

### 3.3 Co-Citation Analysis

Instead of being isolated, scientific articles partake in an interrelated system of research, review, and further research and review that is constantly extending. The mutual citation of scientific articles reflects the accumulation and continuity of scientific knowledge, which is objective. The density of the citation network usually reveals the decentralized and centralized patterns of citation distribution. If two articles co-appear in the reference list of a third citing article, then these two articles are in a co-citation relationship. Co-citation analysis refers to the process of exploring the co-citation relationships between the data sets within a document space (Small, 1973). CiteSpace has powerful co-citation analysis functions, including three node types: cite reference, cite author, and cite journal (Chen, Ibekwe-SanJuan, & Hou, 2010).

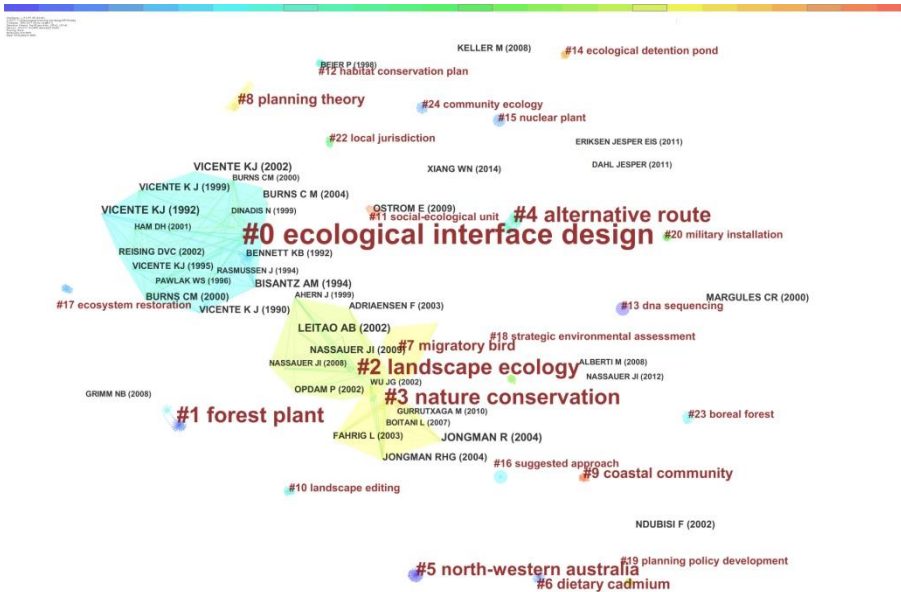


Figure 5. Network clustering of cite-reference in the research field of ecological planning and design

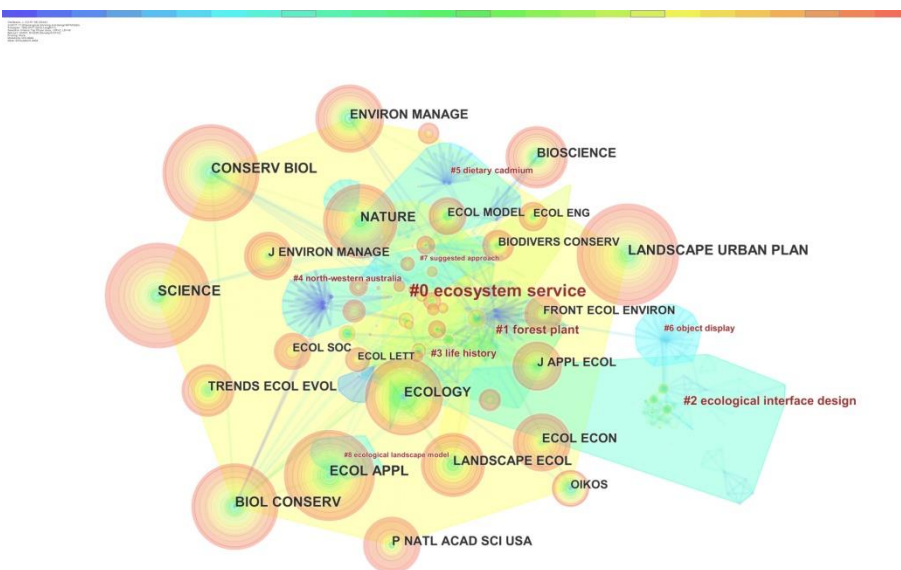
Table 5. The top ranked items of cite-reference by burst

| Burst | First author    | Full journal names  | Year | Frequency | Half-life | Cluster |
|-------|-----------------|---|------|-----------|-----------|---------|
| 4.82  | Vicente K.J.    | Human Factors<br>IEEE Transactions<br>on Systems Man and<br>Cybernetics Part<br>B-Cybernetics | 2002 | 8         | 6         | 0       |
| 4.3   | Vicente K.J.    | Ecological<br>Networks  | 1992 | 8         | 6         | 0       |
| 4.22  | Jongman R.      | Landscape and<br>Urban Planning<br>International  | 2004 | 8         | 6         | 3       |
| 4.21  | Leitao A.B.     | Journal of<br>Human-Computer<br>Studies   | 2002 | 8         | 5         | 2       |
| 3.77  | Bisantz<br>A.M. | Ecological Interface  | 1994 | 7         | 2         | 0       |
| 3.61  | Burns C.M.      | Ecological<br>Psychology  | 2004 | 6         | 4         | 0       |
| 3.6   | Vicente K.J.    | Ecological<br>Psychology  | 1990 | 6         | 7         | 0       |

Based on the results of the co-authorship analysis and the information in Figure 5 and Table 5, relevant information about research articles in the field of ecological interface design was removed - e.g. cluster #0, cluster #6, as well as authors with a high degree of mutation like Vicente K.J., Bisantz A.M., Burns C.M. and Vicente K.J. - to obtain the authors with a high degree of mutation and citation frequency in the field of ecological planning and design

and their research directions. The systematic and extensible nature of scientific literature can be clearly seen in *Figure 5*. The cumulative and continuous content of scientific knowledge in this area can be explored by fully interpreting highly co-cited articles. The mutual citing between articles in cluster #2 (landscape ecology), cluster #3 (nature conservation), and cluster #7 (migratory bird) indicates a close connection between these articles.

[Jongman and Pungetti \(2004\)](#) introduced and explored the concepts, design principles, and implementation strategies of ecological networks in the 21<sup>st</sup> century. [Leitão & Ahern, 2002](#) declare the increasing urgency of applying a sustainable approach to current landscape planning and management worldwide. They also point out that it is necessary to adopt new tools to truly and effectively apply the principle of sustainability based on ecological knowledge in landscape planning and management. Moreover, the authors state that from the perspective of landscape ecology, many quantitative indices are of great significance to sustainable landscape planning and conducive to promoting the theory and practice of landscape planning and achieving sustainable development ([Jongman & Pungetti, 2004](#); [Leitão & Ahern, 2002](#)). As ecosystems are complicated, in addition to relying on scientific data and engineering methods, humanistic factors should also be considered while solving ecological problems and implementing planning and design. Such problems cannot be effectively solved by the linear or rational models in traditional research and practice. Therefore, the transformation of the research paradigm (i.e., transformed from the traditional Bohr's quadrant to Pasteur's quadrant) is crucial in research on ecosystem services. Only in this way can knowledge of relevance, actionability, and efficacy that is useful to practitioners, managers, and researchers be produced ([Xiang, 2013, 2017](#)).



*Figure 6.* Network clustering of cite-journal in the research field of ecological planning and design

*Table 6* ranks the journals by co-citation frequency from high to low. *Science* is the journal with the highest co-citation frequency in the research field of ecological planning and design. *Landscape and Urban Planning*, as the top leading international journal in the industry, is ranked in 2<sup>nd</sup> place by a small margin. *Conservation Biology* is in 3<sup>rd</sup> place (visually shown by the node sizes in *Figure 6*). As indicated by the years when these journals were initially published, *Nature* and *Bioscience* are the first two journals to publish

research results about ecological planning and design, both of which published relevant research results in 1992. However, *Landscape Ecology* did not focus on this field until 2001; therefore, it has the lowest half-life value, relatively weak overall impact in this field, and few cited classic articles. From the perspective of country distribution, American journals are in the dominant position when it comes to the quantity of research articles on ecological planning and design, which account for 60% of the co-cited journals, followed by the Netherlands and England, at 20% each. Journals in Asia, Africa, South America, Oceania and other regions did not enter the top 10. In addition, it can be seen from *Figure 6* that the majority of journals currently focus most on ‘ecosystem service’ (cluster #0) in the field of ecological landscape planning and design.

Table 6. The top ranked items of cite-journal by citation counts

| Frequency | Full journal names           | Year | Half-life | Country     |
|-----------|------------------------------|------|-----------|-------------|
| 150       | Science                      | 1995 | 18        | America     |
| 147       | Landscape and Urban Planning | 1996 | 16        | Netherlands |
| 141       | Conservation Biology         | 1995 | 16        | America     |
| 134       | Ecological Applications      | 1998 | 14        | America     |
| 128       | Biological Conservation      | 1992 | 20        | England     |
| 118       | Ecology                      | 1993 | 17        | America     |
| 110       | Nature                       | 1992 | 20        | England     |
| 104       | Environmental Management     | 1994 | 18        | America     |
| 96        | Landscape Ecology            | 2001 | 11        | Netherlands |
| 95        | Bioscience                   | 1992 | 20        | America     |

### 3.4 Co-Words Analysis

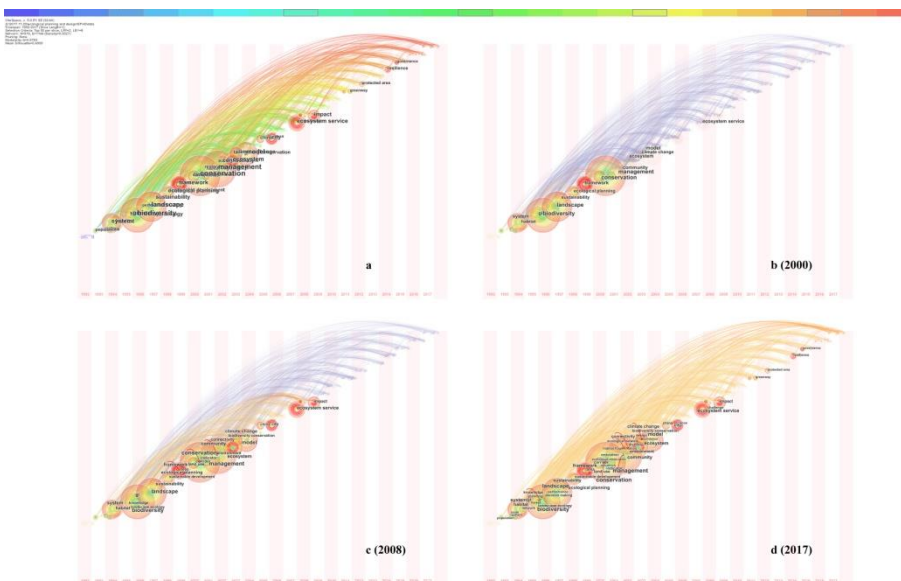


Figure 7. The time-zone view of co-keywords in the field of ecological planning and design

In scientific metrology studies, word frequency dictionaries can be established according to the field of studies so as to quantitatively analyse the achievements made by researchers. The word frequency analysis method can be used to study the development trend and heated research topics in a specific field of science. The basic principle of co-word analysis is to count in pairs the number of times that a group of words appear in the same group of documents. By measuring the number of co-occurrences, the close or distant relationships between them can be measured. Compared with the co-citation analysis,



co-words analysis is more intuitive and specific (Callon, Rip, & Law, 1986). In this study, the Keyword node type of CiteSpace was used to analyse the keywords provided by authors in the data set.

The time-zone view is a view focused on representing the evolution of knowledge from the perspective of time. In the co-keyword analysis, this visualization method can clearly show the updating process of knowledge and how different knowledge mutually influences each other. *Figure 7* is a time-zone view of the literature keywords with a high degree of mutation and citation frequency in the field of ecological planning and design. *Table 7* lists the 30 most frequently cited co-keywords and relevant years of occurrence. *Figure 7a* shows the co-keywords with high citation frequency from 1992 to 2017. The volume of the tree ring history of the ‘conservation’ node in 2000 ranks the first among all the keywords, indicating that articles in this direction were cited most frequently and widely. The ‘management’ in 2001 and ‘biodiversity’ in 1995 are also of great concern to scholars.

*Table 7.* Top 30 keywords with the strongest citation counts

| No. | Keywords                  | Frequency | Year | Burst | Half-life |
|-----|---------------------------|-----------|------|-------|-----------|
| 1   | conservation              | 64        | 2000 | –     | 11        |
| 2   | management                | 58        | 2001 | –     | 12        |
| 3   | biodiversity              | 55        | 1995 | –     | 16        |
| 4   | landscape                 | 48        | 1996 | –     | 16        |
| 5   | model                     | 37        | 2003 | –     | 10        |
| 6   | system                    | 31        | 1994 | –     | 18        |
| 7   | ecosystem                 | 31        | 2002 | 3.89  | 7         |
| 8   | framework                 | 27        | 1999 | 4.1   | 14        |
| 9   | ecosystem service         | 27        | 2007 | 6.11  | 8         |
| 10  | geographic information    | 26        | 1995 | –     | 18        |
| 11  | community                 | 26        | 2001 | –     | 10        |
| 12  | habitat                   | 24        | 1994 | –     | 18        |
| 13  | sustainability            | 21        | 1997 | –     | 16        |
| 14  | ecological planning       | 21        | 1998 | –     | 15        |
| 15  | climate change            | 21        | 2003 | –     | 11        |
| 16  | connectivity              | 20        | 2002 | –     | 12        |
| 17  | impact                    | 20        | 2008 | 3.46  | 4         |
| 18  | land use                  | 19        | 2000 | –     | 13        |
| 19  | city                      | 19        | 2005 | 3.95  | 9         |
| 20  | environment               | 17        | 2002 | –     | 11        |
| 21  | landscape ecology         | 15        | 1995 | –     | 9         |
| 22  | sustainable development   | 14        | 1998 | –     | 14        |
| 23  | indicator                 | 14        | 2000 | –     | 8         |
| 24  | corridor                  | 13        | 2000 | –     | 6         |
| 25  | biodiversity conservation | 13        | 2003 | –     | 13        |
| 26  | forest                    | 11        | 1995 | 3.97  | 15        |
| 27  | diversity                 | 11        | 2002 | –     | 11        |
| 28  | ecological network        | 11        | 2002 | –     | 8         |
| 29  | design                    | 11        | 2003 | 4.39  | 12        |
| 30  | resilience                | 11        | 2014 | 4.45  | 2         |

*Figure 7b* shows a static time-zone view of co-keywords in the field of ecological planning and design from 1992 to 2000. Co-keywords with high citation frequency in this period include ‘conservation’ (64), ‘biodiversity’ (55), ‘landscape’ (48), ‘system’ (31), ‘framework’ (27), ‘geographic information’ (26), ‘habitat’ (24), ‘sustainability’ (21), ‘ecological planning’ (21), ‘land use’ (19), ‘landscape ecology’ (15), ‘sustainable development’ (14), ‘indicator’ (14), ‘corridor’ (13) and ‘forest’ (11). During this period, both developed and developing countries faced problems such as post-industrial brownfields and environmental degradation. Landscape suitability analysis methods, e.g. the application landscape ecological method and the application ecological system method—are gradually maturing, and



3S technologies are becoming popular. In this context, ecological planning, design, restoration, and management of urban-scale forests and river basins, oriented towards land-use, have drawn great attention from practitioners and researchers, and promising achievements have been made ([Dutilleul, 1993](#); [Xiang, 1996](#)).

In the first decade of the 21<sup>st</sup> century (*Fig. 7c*), as clearly indicated by the appearance of co-keywords with high citation frequency such as 'management' (58), 'model' (37), 'ecosystem' (31), 'ecosystem service' (27), 'community' (26), 'climate change' (21), 'connectivity' (20), 'impact' (20), 'city' (19), 'environment' (17), 'biodiversity conservation' (13), 'diversity' (11), 'ecological network' (11), 'design' (11), ecosystem services and the total human ecosystem with systemic thinking and humanistic ecological orientation have developed rapidly, and biodiversity conservation and ecological community design have become hot research topics ([Opdam, Steingröver, & van Rooij, 2006](#)).

'Resilience' (11), the high-frequency co-keyword of 2014 in *Figure 7d*, is a hot word appearing in physical, psychological, management and ecological research during recent years. Research on resilience in the ecological field mainly focuses on ecological environment, agriculture, and urban planning. 'Resilience' is used to highlight the resilience of the ecological system, however, it currently emphasizes the system's ability to maintain its basic structure and functions by stopping, absorbing, and adapting to external interference. Instead of overemphasizing the equilibrium the system, it affirms the transformation and adjustment of the system ([Anderies, 2014](#); [Pickett, Cadenasso, & Grove, 2004](#)). Although research on resilience in the field of ecological planning and design have just started, they deserve continuous attention and discussion for their wide influence and the rapid development of relevant theories.

#### 4. CONCLUSIONS

Ecological planning (or ecological design) is an effective way to coordinate the relationship between human activities and development. It has become increasingly important after nearly a century of theoretical evolution and practical testing. Nowadays, there are diversified characteristics when it comes to research, methods, and practices about ecological planning, and the structure of traditional knowledge has become more and more complicated as well. Visual analysis based on bibliometrics provides a new perspective and a method for quickly clarifying the knowledge structure, research hotspots, and research trends in a particular field. CiteSpace can not only translate massive document data into intuitive visualization maps, but also can detect information hidden in large volumes of literature that would otherwise be imperceptible.

Through the co-authorship analysis, co-citation analysis, and co-words analysis of the 712 WoS articles studied here, the author believes that in the era of knowledge sharing and cooperation, the cooperation between countries, research institutions, and scholars in the field of ecological planning and design should be strengthened. In particular, China and its research institutions should extensively participate in international scientific research cooperation and actively publish the latest scientific research results in their academic circles. Moreover, scholars from different regions and countries should seize opportunities for cooperation in the field of ecological planning and design. At the current stage, developed European and American countries

outweigh Asian countries in terms of research results and overall influence in the field; the popularity and influence of journals concerned with ecosystem services from Asian countries remain to be improved. In addition, it is crucial to transform the research paradigm of ecological planning and design, which is the necessary condition for theoreticians to produce useful knowledge for practitioners. The gradual degradation of the natural landscape caused by human activity requires that in ecological planning, people should follow the principle of 'Design with Nature'. A consensus should be reached among researchers, managers, and practitioners. The idea that planning should be based on ecology should be carried out in the planning of large-scale projects, and the methods and principles of integrating ecological concepts in planning and design should continue to be improved. What can also be seen from the co-keyword analysis conducted above is that the trend of ecological planning and design research is becoming increasingly systematic, comprehensive, and humanistic. Moreover, resilience has become a research hotspot in this field in recent years. Thus, appropriate attention should be paid to these aspects.

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